Evaluation of the 2008 Rebuilding Plan for Celtic Sea Herring

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Abstract

This document outlines the evaluations conducted on the 2008 rebuilding plan for Celtic Sea and VIIj herring. Though the plan was evaluated by ICES, that evaluation was never subsequently published, nor does it appear in any ICES report. This document summarises the evaluation carried out by the Marine Institute, for ICES, and presents the independent reviews conducted on its behalf. It also evaluates the subsequent performance of the plan. The ICES advice for 2007, 2008 and 2009 has been that there should be no targeted fishing without a rebuilding plan. In 2008, the CSHMAC presented a rebuilding plan to the European Commission and Council, via the recently established Pelagic Regional Advisory Council (PRAC). The plan was not formally adopted, but the TAC for 2009 was consistent with the plan. Subsequently, in early 2009, the plan was recognised by the European Commission. The plan was developed during a series of iterations, through discussions between industry representatives and scientists, within the CSHMAC. The final plan consisted of a Harvest Control Rule (HCR), a formalised decision rule defining the level of F to be applied in future, given the current position of SSB and F relative to their reference values. The proposal was forwarded to the Pelagic Advisory Council where it was endorsed before being sent for consideration by the European authorities. The European Commission considered the plan to be worthy of being evaluated by ICES. It was adopted for TAC setting for 2009, by the European Council of Ministers and was sent for evaluation by ICES for conformity with the Precautionary Approach to Fisheries Management (PAFM).

Keywords: herring *Clupea harengus*, Celtic Sea, rebuilding plan. harvest control rule, stakeholder consultations, management plan development.

Contents

1 Introduction

The Celtic Sea herring (*Clupea harengus*) stock comprises both autumn and winter spawning components from ICES divisions VIIa South and VIIg,h,j and k which are located to the south and southwest of Ireland (Figure 1). This herring stock is at the southern edge of the species' distribution in the north east Atlantic. It has shown wide - though trendless - fluctuations in productivity over time (ICES, 2007a) and supports economically and socially important fisheries.

This stock has been subject to a total allowable catch (TAC) since 1974, and has been managed under the European Common Fisheries Policy since 1983 (Molloy, 2006). In the early 2000s, the stock collapsed. This is defined as the spawning stock biomass (SSB) falling below the precautionary limit reference point (B_{lim}), the level below which recruitment impairment is expected. The stock history is presented in Figure 2, based on the assessment conducted by the International Council for the Exploration of the Seas (ICES, 2012). Stakeholder input to management has been a feature of this stock since 1983, when a consultative industry-led committee was established. This development was based on a desire, within the fishing industry, to avoid another stock collapse, like the one that happened in the late 1970s (Molloy, 2006). This committee existed in various forms and degrees of influence between 1983 and 2001, though it had no statutory footing. In 2001 a new body, the "South and West Pelagic Management Committee", or SWPMC, was convened. The committee received Ministerial recognition in 2005, by which time its remit had been restricted to herring. It is officially called the "Celtic Sea Herring Management Advisory Committee" or CSHMAC.

The ICES advice for 2007, 2008 and 2009 had been that there should be no targeted fishing without a rebuilding plan. In 2008, the CSHMAC presented a rebuilding plan to the European Commission and Council, via the recently established Pelagic Regional Advisory Council (PRAC). The plan was not formally adopted, but the TAC for 2009 was consistent with the plan. Subsequently, in early 2009, the plan was endorsed by the Commission. The plan was developed during a series of iterations, through discussions between industry representatives and scientists, within the CSHMAC. The final plan consisted of a Harvest Control Rule (HCR), a formalised decision rule defining the level of F to be applied in future, given the current position of SSB and F relative to their reference values. The proposal was forwarded to the PRAC where it was endorsed before being sent for consideration by the European authorities. The European Commission considered the plan to be worthy of being evaluated by ICES. It was adopted for TAC setting for 2009, by the European Council of Ministers and was sent for evaluation by ICES for conformity with the Precautionary Approach to Fisheries Management (PAFM).

The plan (Table 1) incorporated scientific advice with the main elements of the EU policy statement. A schematic representation of the plan is shown in Figure 3. In the rebuilding plan the $SBB_{trigger}$ = 26,000 t, if SSB ≥ $SBB_{trigger}$, fishing mortality in the following year is set such that F = $F_{0.1}$ (estimated as F = 0.19) and if SSB < $B_{trigger}$ a 25% reduction in TAC would apply in the following year.

The draft plan was followed *de facto* for management of the stock in 2009, 2010, 2011 and 2012, though due to legal difficulties within the EU, it never had any legal standing. The TAC setting mechanism for 2009 corresponded with the stated policy of the European Commission and was adopted by the Council. Thus, the draft rebuilding plan proceeded in parallel with management under the EC Common Fisheries Policy. Meanwhile, the closed area provision of the plan was implemented by Irish legislation from 2009 onwards, having been established on a voluntary basis since 2007. Only Ireland fished the stock in that area, so it only required action from Ireland.

In March 2009, the European Commission asked ICES (text of Commission interpretation in text table below) to evaluate the plan. ICES was asked to evaluate if points 2 and 3 of the plan were precautionary:

- For 2010 and subsequent years the TAC will be set consistent with a fishing mortality rate of $F_{0.1} = 0.19$.
- If, in the opinion of ICES and STECF the catch should be reduced to the lowest possible level, the TAC for the following year will be reduced by 25%.

In answering this request, ICES judged the plan to be in accordance with the PAFM, though it was noted that the plan would have to be re-evaluated if successive poor recruitments were to occur (ICES, 2009a).

Though the plan was evaluated and approved by ICES, that evaluation was never subsequently published, nor does it appear in any ICES report. Therefore, this document summarises the evaluation carried out by the Irish Marine Institute, for ICES, concerning points 2 and 3 of the proposed plan and presents the independent reviews conducted on behalf of ICES. It also evaluates the subsequent performance of the plan.

2 Materials and Methods

2.1 Forward Simulation of the HCR

Evaluation of the final HCR was performed using HCS-Celtic (Skagen, 2009). The program was developed for stochastic simulation of harvest control rules. The program imitated the normal advisory process where the stock is assessed one year before the year for which the TAC is set. A projection was made through the intermediate year to obtain the stock abundance at the start of the TAC year. HCS mimicked that process without running actual assessments as part of the simulations. Instead, observation errors were specified as distributions and carried forward in predictions to get the stock abundances that formed the basis for management decisions.

The program consisted of a population model that generated yearly stock numbers at age, an observation model applying uncertainty to the stock numbers, a decision rule through which a TAC is derived according to the observed stock (projected forward if relevant) and an implementation model that translates the TAC into actual removals. Figure 4 presents a schematic outline of the simulation loop. The routine incorporated a series of bootstraps of the initial population numbers, recruitments, observation errors, and implementation errors.

This model was an adaptation of the original HCS model (Skagen, 2008). HCS–Celtic included an extra feature to test the effect of zero catch on SSB. If SSB < B_{lim}, then a TAC reduction of 25% applied, otherwise, $F_{0.1}$ applied. A subsequent modification was made which derived an SSB for input to the harvest control rule assuming a reduced TAC in the fishing year.

Sensitivity analysis was conducted to evaluate the effect of including observation and implementation error and bias. HCS computes risk to B_{lim} by calculating the number of trajectories (in percent) where SSB<B_{lim} at least once in the time period.

Simulations carried out to evaluate the rebuilding plan had 2009 as the starting point. The age range used in the population model was 1-6 winter rings, with mean fishing mortality calculated over ages 2-5 winter rings. The 2009 population numbers were taken from the final assessment in 2009. Following the procedure of the assessment and forecast, 1 ringers were replaced with geometric mean recruitment from 1995-2006. Population numbers of 2 ringers in the intermediate season (2009) were calculated by the degradation of the geometric mean recruitment (1995-2006). Natural mortality was assumed to be constant every year. Selection at age, mean weights in the catch and in the stock are calculated as averages over the last three years (2006-2008). The maturity ogive for this stock assumes that 50% of 1 ringers, and 100% of subsequent ringers are mature. Input data are presented in Table 2.

Three estimates of intermediate catch in 2009 were used. This was necessary because the catch in the intermediate year (2009/2010) includes the first quarter of the advice (TAC) year. Therefore the TAC set for 2010 influences the intermediate year catch. The interim year catches estimates were as follows:

- 6,809 15% increase based on EU TAC Decision Rule for stocks where SSB is increasing (ICES, 2009).
- 7,507 56% increase, based on F0.1 (2009) = 0.17.
- 7,763 71 % increase, based on F0.1 (2007) = 0.19.

Apart from the two alternative interim year catches, all of the inputs described above were used in the forecasts that were carried out at the 2009 working group (Table 2). Unaccounted fishing mortality was included in the model as a +10% implementation bias. The coefficient of variation corresponding to observation and implementation error was set at 20%. The uncertainty at age was taken from the ICES assessment (ICES, 2009b). All runs are summarised in Table 3.

2.2 Stock Recruitment Relationship

The stock recruit data did not display a clear pattern with fluctuations in SSB and recruitment evident throughout the time series, and large recruitments at low biomass. The stock recruitment data suggest that the classical models were not applicable. Examination of the Akaike's information criterion (AIC), showed the segmented regression offered the best representation. The segmented regression was therefore chosen, and provided an independent estimate of the breakpoint i.e. the SSB, below which recruitment impairment is considered to occur. SSB breakpoint was estimated at 41,000 t. The estimate of breakpoint was close to recent estimation of 47,000 t, STECF, 2006.

The segmented regression stock-recruit relationship was used and applied to data for 1958-2006. Data from the most recent two years (2007 and 2008) were excluded because they were less well estimated. Model fitting was conducted in R (http://www.r-project.org/) using the algorithm of Julios (2001), see Figure 5. The SSB breakpoint was estimated at 41,000 t, and the plateau level of recruitment at 416 million individuals (Table 4). A log-normal distribution of the recruitments was assumed. The distribution was truncated at 0.1 and 3.0 to avoid drawing recruitments far outside the historical range. The modelled and expected distributions of recruitments are shown in the Figure 6. At cumulative probability 0.2 to 0.5 the model predicted lower recruitment than observed, though elsewhere there was excellent agreement.

2.3 Stock assessment

The ICES stock assessments from 2009-2012 were used to evaluate the main indicators of stock status, SSB, F and landings (ICES, 2009b; 2010; 2011a; 2012). In 2009, a benchmarked assessment, considered reliable to forecast catch options for the following year was produced by ICES. This was the first definitive assessment and forecast of the stock since before the collapse, and subsequent assessments followed the standard operating procedures developed in 2009.

3 Results

3.1 Forward Simulation of the HCR

A number of scenarios were tested, using several runs of the modified HCS-Celtic program. Initial runs investigated a broad range of target F levels (0.2-1.0), trigger biomass ($B_{trigger}$ 26,000 – 44,000), and % reductions (25% - 75%) when SSB<$B_{trigger}$. The results of these broadscale runs are presented in contour plots, showing target F on the horizontal, and $B_{trigger}$ on the vertical, with separate rows for the different % reductions, and columns for year combinations (Figure 7 and 8). The legend of probabilities (SSB<B_{lim}) is provided on the right, in terms of colours. According to ICES common practice, levels of less than 5% are considered to be in accordance with the precautionary approach.

Subsequent runs (Table 5) tested a narrower range of target Fs, in the range of $F_{0.1.}$ $F_{0.1}$ has been estimated as 0.17 (ICES, 2009b) and 0.19 (ICES, 2007a). Therefore target F values in the range 0.17 to 0.19 were evaluated. These runs were to simulate the rebuilding plan as requested by the Commission. These runs also considered the sensitivities of various factors including CV, bias, interannual variation in TAC and intermediate year catch.

Results of initial runs are shown in Figure 7 (without bias), and Figure 8 (with bias). Summary plots showing F, SSB, risk and yield over the simulation period are shown in Figures 9-12. The results of initial screening (Run 1) showed that target Fs above 0.4 have increased risk of SSB<$B_{trigger}$. These simulations suggest that a target F in the range up to 0.4 is precautionary at any chosen trigger biomass up to 45,000 t and any % reduction from 25% to 75%. Unacceptable risks are associated with target F above 0.6. At high target F, risk is lower when a higher $B_{trigger}$ is chosen. The inclusion of implementation bias (10%) did not alter the risk profile appreciably (Figure 8). From Figure 12 it can be seen that risk to B_{lim} is predicted to increase to unacceptable levels by 2012 and that target F in the range 0.6 to 1.0 is predicted to lead to B_{lim} at some point in the simulation period. Figure 13 shows risk profiles for the first and second 10-year periods of the simulation. There was increased risk associated with higher target F, and lower $B_{trigger}$ in the second period.

Initial screening suggested that target F, in the range of recently proposed $F_{0.1}$ estimates, is precautionary. Subsequent simulations concentrated on a range of F in this region. The base case scenario that was tested considered three $F_{0.1}$ estimates, $B_{trigger}$ = B_{lim} from the proposed rebuilding plan and the proposed percentage reduction when SSB < B_{lim} (Run 3). A 10% implementation bias was considered appropriate and CV on the observation and implementation models was fixed at 20%. This was based on an interim year catch of 7,763 t (F=0.19).

Figures 14-17 show trajectories of realised F and yield, SSB and risk to B_{lim} for this run, and Appendix 1 contains detailed outputs. This F range is associated with minimal risk (<1%) to B_{lim}, and a building of the stock to levels where yields of about 13,000 t are realised over the latter part of the simulation period. The highest target F (ICES, 2007; $F_{0.1}$) does not increase the risk to any appreciable degree and is associated with similar yields.

The sensitivity of the base case run was tested against several factors, namely:

- Inter-annual TAC variation (Runs 4)
- Precision and bias on observation model (Runs 5 and 6 respectively)
- Precision and bias on implementation model (Runs 7 and 8 respectively)
- Interim year catch (Runs 9 and 10)

It was not appropriate to investigate the effect of changing the % reduction of TAC when SSB < B_{lim}. This was because the range of F's in the region of $F_{0.1,}$ which is specified in the proposed plan do not bring the SSB below B_{lim} or the other trigger points chosen.

The risk profiles for these sensitivity runs are presented in Figures 18 to 20. In the F and $B_{trigger}$ region of the proposed plan, no IAV was associated with a risk to $B_{lim,}$ that was appreciably lower than the base case (Figure 18). The proposed rebuilding plan appeared robust to a plausible range of implementation errors and biases (Figure 19). Slightly higher risk was found to be associated with an observation CV of 40%. None of the likely interim year catches altered the risk profile to any extent (Figure 20).

3.2 Stock Assessment

Results of the 2012 ICES stock assessment (ICES, 2012) are presented in Figure 2. The pertinent results of all assessments 2009-2012 are presented also in Table 5. It can be seen that SSB recovered to above B_{pa} by 2008. By 2011, three successive terminal year estimates of SSB were above B_{pa}. Also, by 2011, three succesive assessments were available which confirmed SSB to be consistently, and without downward revision, above B_{pa}. Therefore, within in its own terms, the rebuilding plan had reached its conclusion (Table 5).

4 Discussion

4.1 Results of simulations for conformity with the precautionary approach

The simulations conducted in this exercise predicted that the proposed rebuilding plan was consistent with the precautionary approach to fisheries management. Target F in the range of recent estimates of $F_{0.1}$ is not associated with risk of SSB < B_{lim}. The exercise did not attempt to evaluate the effect of the closed area (Points 4 and 5), as this was not requested of ICES by the European Commission. However future work should aim to evaluate the impact of this measure, which predates the formal rebuilding plan.

The proposed 25% TAC reduction when SSB < B_{lim} was shown to be precautionary, when target F < 0.4. At higher target F, acceptable risks were associated with a 75% TAC reduction, and $B_{trigger}$ in range of 40,000 t to 45,000 t. These simulations were based on the best estimate of 2009 stock size, and low historic catch levels. However, if the stock was decreasing and catches were at levels observed historically, then it is not clear if a 25% reduction would have been precautionary.

Point 3 may not be appropriate for a long term management plan for this stock. The current simulations are only relevant to the proposed rebuilding plan. However following this plan there will be minimal risk to $B_{lim.}$ Thus, the overall rule in the plan is precautionary, if the target F in point 2 is followed.

4.2 Interpretation of the rebuilding plan

The clause “the catch should be reduced to the lowest possible level, the TAC for the following year will be reduced by 25%”, in point 3 of the plan may lead to some confusion. This was a standard wording used in the EU policy statements on the fixing of catch opportunities. The stakeholder committee intended this text to represent the scenario, when the scientific advice is for a zero-catch. This would apply if the $SSB_{TAC\ year} \leq B_{lim}$. In this scenario, the plan provides for a 25% reduction in TAC, *not* TAC = 0.

4.3 Stock dynamics and the population model

It is important that the stock dynamics are well understood and an adequate basis for simulating the plan. The underlying population model was that of the 2009 accepted ICES assessment (ICES, 2009b). This was considered an extension of the 2007 benchmark assessment of this stock. The independent reviewers endorsed the decisions made and concluded that the assessment methodology was "generally sound", but with "some inconsistencies" (Cadrin et al. 2009). These inconsistencies were as follows:

a. Short survey series, with weak relationships to canum and some year effects.
b. A large portion of the spawning stock composed of 1-ringers, that were poorly estimated.
c. Assumption of constant selectivity.
d. Assumed selectivity at the oldest ages for the entire time series possibly leading to misinterpretation of the apparent shifts in age selectivity by the fishery.
e. No estimates of discards.
f. Consumption of herring as forage not estimated.
g. Mixed-stock resource and connectivity with adjacent management units assessment should be developed.

Points a, b, c, and d above represent structural aspects of the fisheries data that could not be improved on at the time. The survey data used represented the longest time series of comparable surveys available. The poor estimation of 1-ringers could only be improved when a recruit series is available. The population model assumes 50% maturity at 1-ringer, which is a compromise. It is known that more than 50% of fish in Celtic Sea catches are mature at 1-ring (Lynch, 2009). However these are probably fast growing recruits. On the other hand, slower growing fish, present in the Irish Sea (Brophy and Danilowicz, 2002), may have a later maturity. The selection assumption seems valid for the separable period assumed in the model as the fishery pattern has been relatively constant over this period. This evaluation exercise is comparable with others conducted recently on West of Scotland herring, NEA mackerel and western horse mackerel, where discarding was either not accounted for at all, or else not fully accounted for in the observation model, and as noted by a reviewer, is very similar to a management strategy evaluation for North Sea cod (Pawlowski, 2009).

The consumption of herring as forage by predatory marine animals has not been evaluated in the population model. No good estimates of herring consumption exist in this area. Natural mortality in many herring stocks is poorly understood. Recent agreed management plans for west of Scotland herring and horse mackerel were based on data that did not explicitly consider the forage consumption. Though the approach taken for Celtic Sea herring is broadly comparable with other stock assessments, it is clear that more work needs to be done on the level of consumption of herring as forage.

Point g of the review group's comments is considered to add uncertainty to the stock dynamics. The current stock assessment model does not consider the effect the mixing of juveniles, and indeed adults, of this stock with the neighbouring Irish Sea stock. One approach to this problem would be to employ a two stage assessment model as used by Roel et al. (2009). Another approach would be to use the framework developed by Kell et al. (2009). It was intended to use this framework to evaluate the proposed rebuilding plan. However, insufficient time was available to develop the program, which is currently not fully operational.

4.4 Stock recruitment relationship and recruitment variability

The stock recruitment data do not suggest that any of the classical models (Beverton and Holt, Ricker, Shepherd) are applicable. The data show low and high recruitments at low and high stock size. The segmented regression was chosen, and provided an independent estimate of the changepoint SSB, below which recruitment impairment is considered to occur. The estimate of change point (41,000 t) is close to recent estimates (45,000 t; STECF, 2006; 47,000 t; ICES, 2009b). Therefore 41,000 t might be a better basis for B_{lim} (Appendix 2b). However, this reviewer acknowledges that the B_{lim} is formally established as 26,000 t and that this was the appropriate value upon which to judge the pre1cautionarity of the plan. It should also be pointed out that ICES guidelines on the limit reference points state that where there is a wide range of recruitment values at low stock size, lowest observed biomass (B_{loss}) should be used as the basis of B_{lim}, and hence the value of 26,000 t corresponds with B_{loss} (ICES SGPA 1998). Recent recruitment has fluctuated around a mean level of 360 million, lower than the long term mean estimated by the segmented regression model (416 million). The stock recruitment relationship may produce higher recruitments in the simulation period, than have been observed in the recent past. However, sensitivity analysis suggests that results are robust to error and bias in the observation model.

4.5 Progress towards F_{msy} by 2015

According to the political commitment at the World Summit on Sustainable Development at Johannesburg, in September 2002, fish stocks should be maintained at or restored to levels that can produce maximum sustainable yield, not later than 2015. The current exercise did not seek to estimate F_{msy}. However, F0.1 can be used as a proxy for F_{MSY}.

5 Conclusions

In answer to the specific questions posed by the European Commission the following answers can be given:

1. Setting a TAC, consistent with a fishing mortality rate of $F_{0.1}$ = 0.19, for 2010 and subsequent years was found not to be associated with an unacceptable risk of SSB < B_{lim}, in the simulation period 2009-2029.

2. If TACs consistent with F in the range 0.17 to 0.19 were set, then there was found to be minimal risk that SSB < B_{lim} in the simulation period 2009-2029. However if fishing takes place at F > 0.4 the 25% TAC reduction in the proposed plan may not have been precautionary.

The proposed rebuilding plan for Celtic Sea and Division VIIj herring was estimated to be in accordance with the precautionary approach, if the target fishing mortality of $F_{0.1}$ is adhered to. This conclusion was supported by two independent reviewers (Appendix 2).

Tables and Figures

Table 1. Text of the rebuilding plan as agreed by the Pelagic RAC in 2008.

1. For 2009, the TAC shall be reduced by 25% relative to the current year (2008).
2. In 2010 and subsequent years, the TAC shall be set equal to a fishing mortality of $F_{0.1}$.
3. If, in the opinion of ICES and STECF, the catch should be reduced to the lowest possible level, the TAC for the following year will be reduced by 25%.
4. Division VIIaS will be closed to herring fishing for 2009, 2010 and 2011.
5. A small-scale sentinel fishery will be permitted in the closed area, Division VIIaS. This fishery shall be confined to vessels, of no more than 65 feet in length. A maximum catch limitation of 8% of the Irish quota shall be exclusively allocated to this sentinel fishery.
6. Every three years from the date of entry into force of this Regulation, the Commission shall request ICES and STECF to evaluate the progress of this rebuilding plan.
7. When the SSB is deemed to have recovered to a size equal to or greater than B_{pa} in three consecutive years, the rebuilding plan will be superseded by a long-term management plan.

Table 2. Input data used in the simulations. Data were taken from the final assessment presented by ICES in 2009, as was the case in the simulations to evaluate the plan.

Age	**Weight in the stock (kg)**	**Weight in the catch (kg)**	**Proportion Mature**	**F**	**Population Numbers 2009**	**Natural Mortality**
1	0.078	0.086	0.5	0.008	360168	1
2	0.107	0.110	1	0.080	131499	0.3
3	0.126	0.131	1	0.137	145357	0.2
4	0.148	0.149	1	0.147	44017	0.1
5	0.157	0.164	1	0.137	84238	0.1
6	0.166	0.175	1	0.137	22269	0.1

Table 3. Details of simulation runs conducted.

Run	Type	Int catch	F target	$B_{trigger}$	% TAC redn.	Notes
1	Broadscale	7763	0.2-1.0	24-44 K	25-75	
2	Broadscale	7763	0.2-1.0	24-44 K	25-75	
3	Base case	7763	0.17-0.19	26-44 K	25	
4	Sensitivity	7763	0.17-0.19	26-44 K	25	IAV 5-25%
5	Sensitivity	7763	0.17-0.19	26-44 K	25	Obs CV 0.2 - 0.4
6	Sensitivity	7763	0.17-0.19	26-44 K	25	Obs. Bias -0.1 to 0.5
7	Sensitivity	7763	0.17-0.19	26-44 K	25	Imp. CV 0.1 to 0.3
8	Sensitivity	7763	0.17-0.19	26-44 K	25	Imp. bias 0.1 to 0.3
9	Sensitivity	7507	0.17-0.19	26-44 K	25-75	
10	Sensitivity	6809	0.17-0.19	26-44 K	25-75	

Table **4**. Parameters of the segmented regression model fit for Celtic Sea herring, 1958-2006.

Slope	Mean recruitment (thousands)	Change point SSB (tonnes)	SSQ	p	S.E
10.17	416,424	40,944	16.37	0.06	0.60

Table 5. Spawning stock biomass, in tonnes, (SSB) as estimated by assessments conducted in 2009-2012 inclusive. Assessment year is indicated on the left hand column, and SSB years along the top row. Shading indicates SSB < B_{pa} (44,000 t).

Assess.	2003	2004	2005	2006	2007	2008	2009	2010	2011
2009	29,084	23,736	32,302	38,689	40,553	70,141	-	-	-
2010	34,703	29,139	41,065	50,463	53,651	70,958	74,689	-	-
2011	34,682	29,076	41,875	52,471	57,743	78,351	105,903	114,319	-
2012	29,223	22,819	30,274	36,930	39,072	51,306	69,145	84,263	85,366

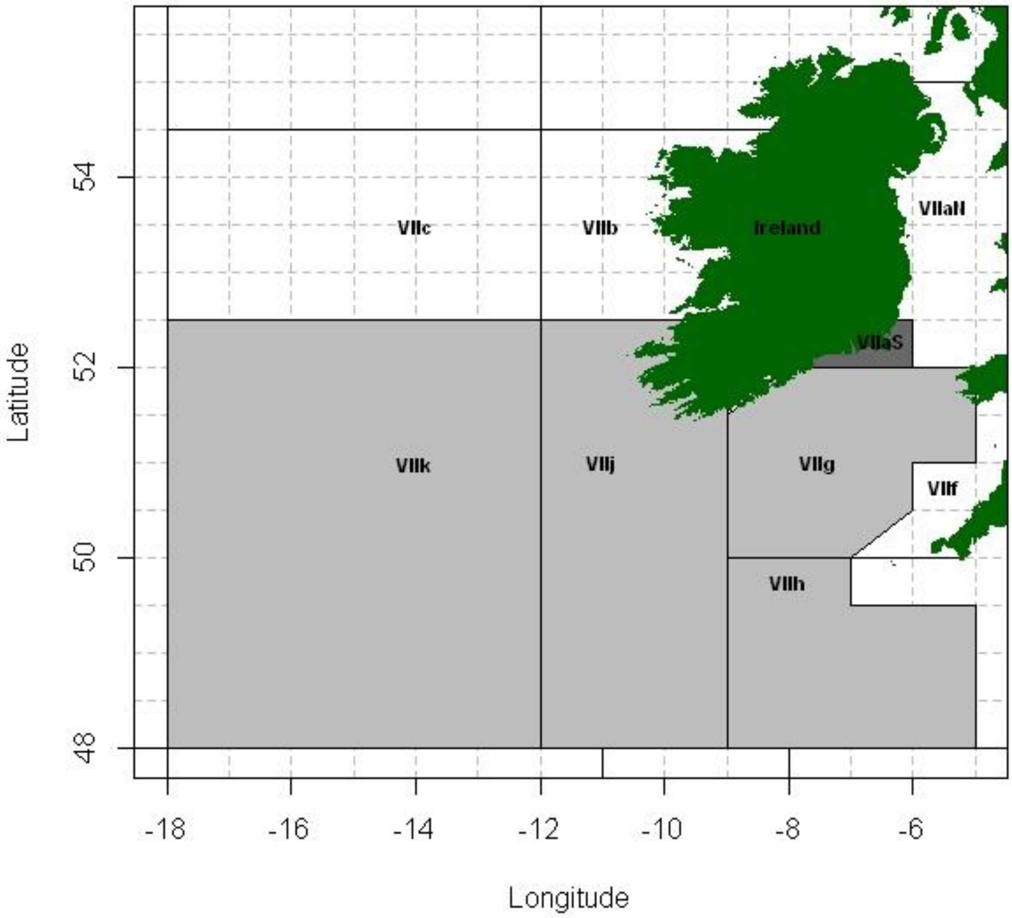


Figure 1. Map showing the Celtic Sea Herring stock area. The closed area of VIIaS is shaded in dark grey.

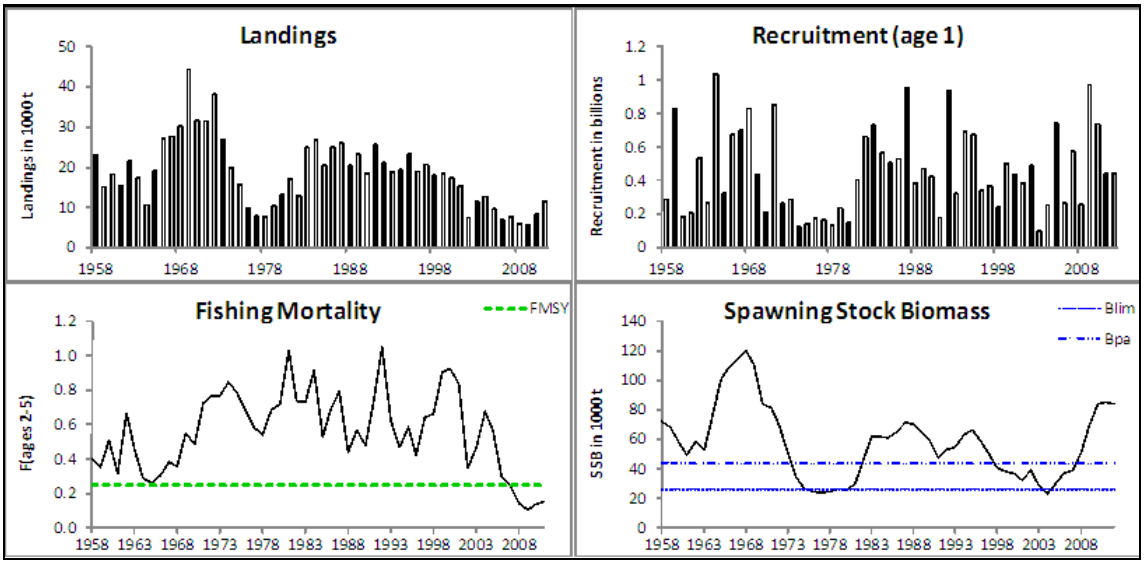


Figure 2: Historical development of the stock over time as estimated by ICES, 2012, clockwise from top left: landings (000 tonnes); recruitment (billions) at age 1; spawning stock biomass ('000s tonnes) precautionary biomass reference points indicated ; fishing mortality (Fyr^{-1}) over ages 2-5 .

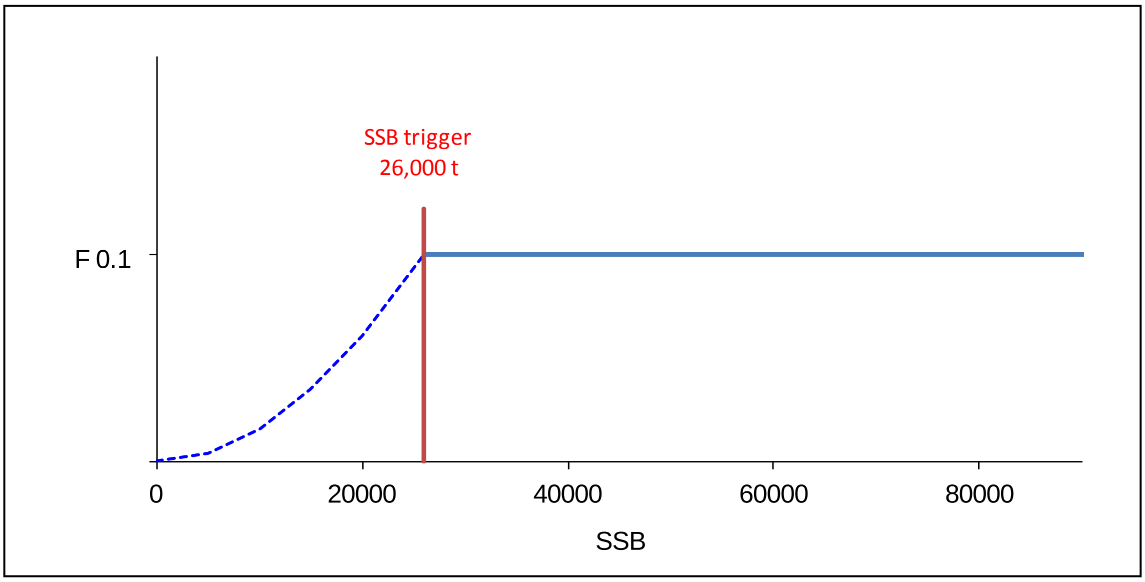


Figure 3. Schematic representation of the harvest control rule element of the rebuilding plan. The $SBB_{trigger}$ = 26,000 t, if SSB ≥ $SBB_{trigger}$, fishing mortality in the following year is set such that F = $F_{0.1}$ (estimated as F = 0.19) and if SSB < $B_{trigger}$ a 25% reduction in TAC would apply in the following year.

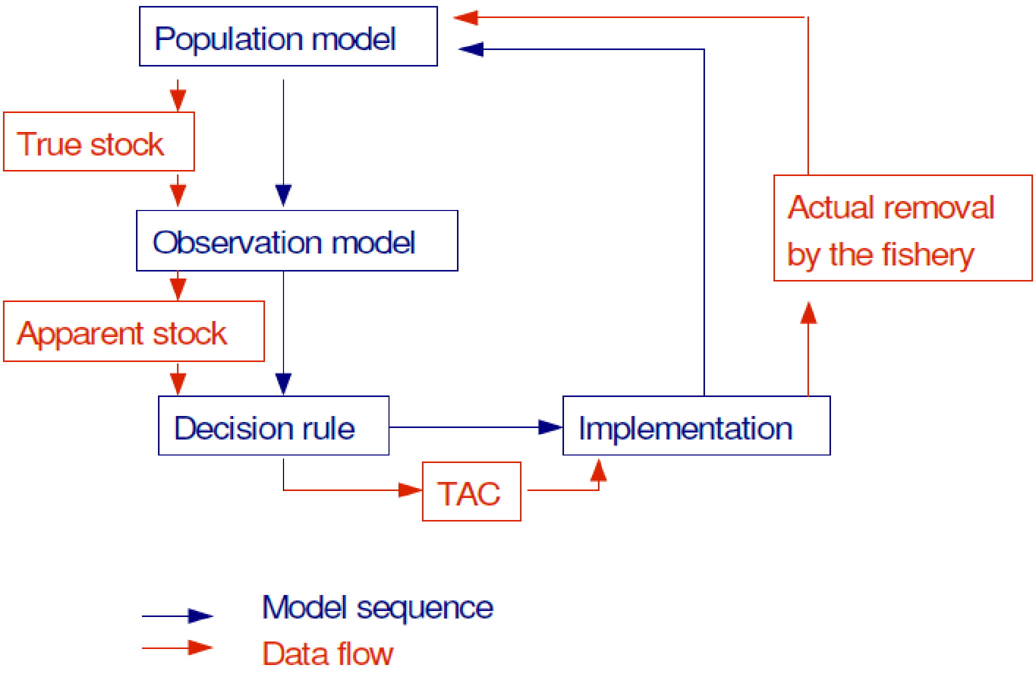


Figure 4. Schematic outline of the simulation loop in the HCS 10 program (Skagen, 2009).

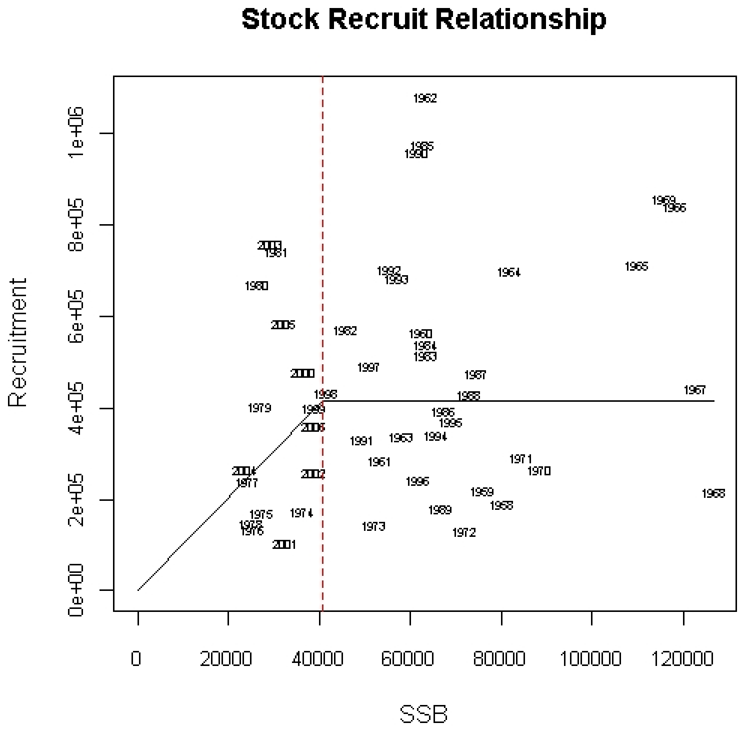


Figure 5. Segmented Regression Stock Recruit Relationship fitted using Julios Algorithm.

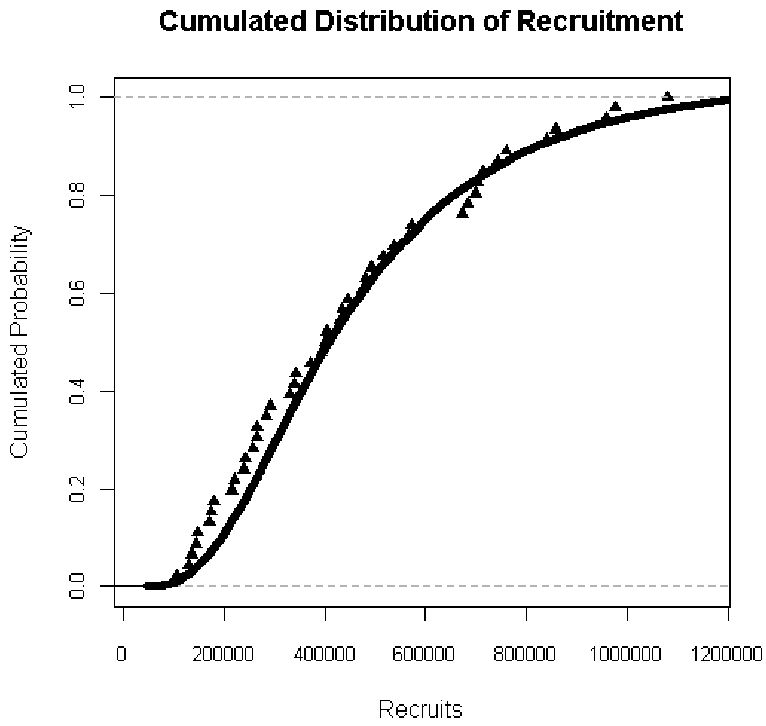


Figure 6: Cumulative probability distribution of observed and modelled recruitment.

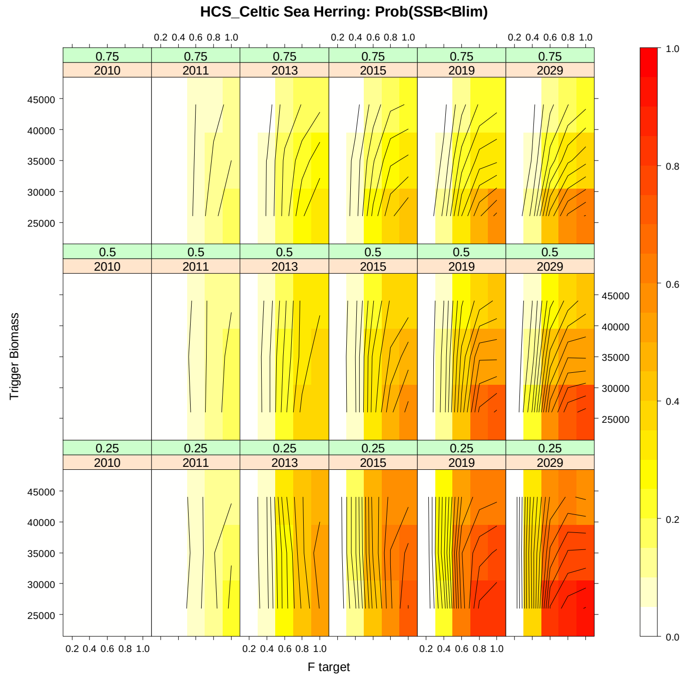


Figure 7. Contour plot showing the probability that SSB < B_{lim}. Run 1, broad scale screening without implementation bias. The x-axis shows potential target F over a broad range, and the y-axis the differing levels of trigger biomass. Each line represents a % TAC reduction, to be implemented if SSB <B_{lim} (25%, 50% and 75%).

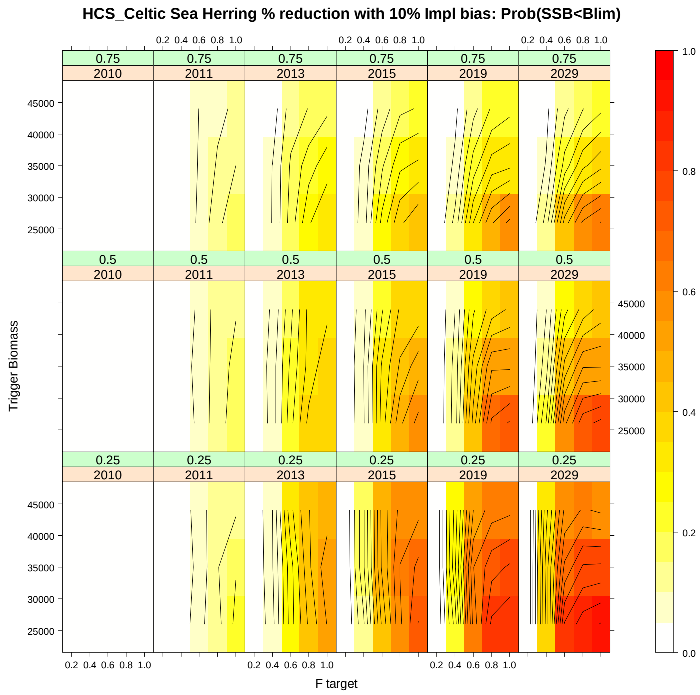


Figure 8. Contour plot showing the probability that SSB < B_{lim}. Run 2, broad scale screening with implementation bias. The x-axis shows potential target F over a broad range, and the y-axis the differing levels of trigger biomass. Each line represents a % TAC reduction, to be implemented if SSB <B_{lim} (25%, 50% and 75%).

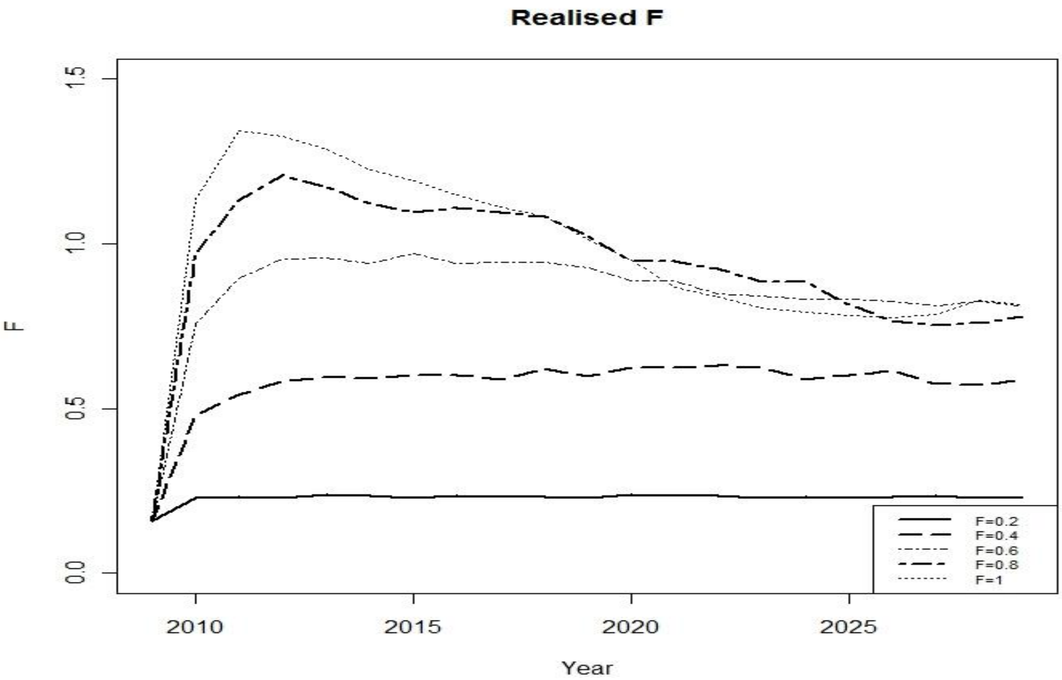


Figure 9. Trajectory plots for broad scale screening exercise (Run 2). Simulated trajectories for realsied F.

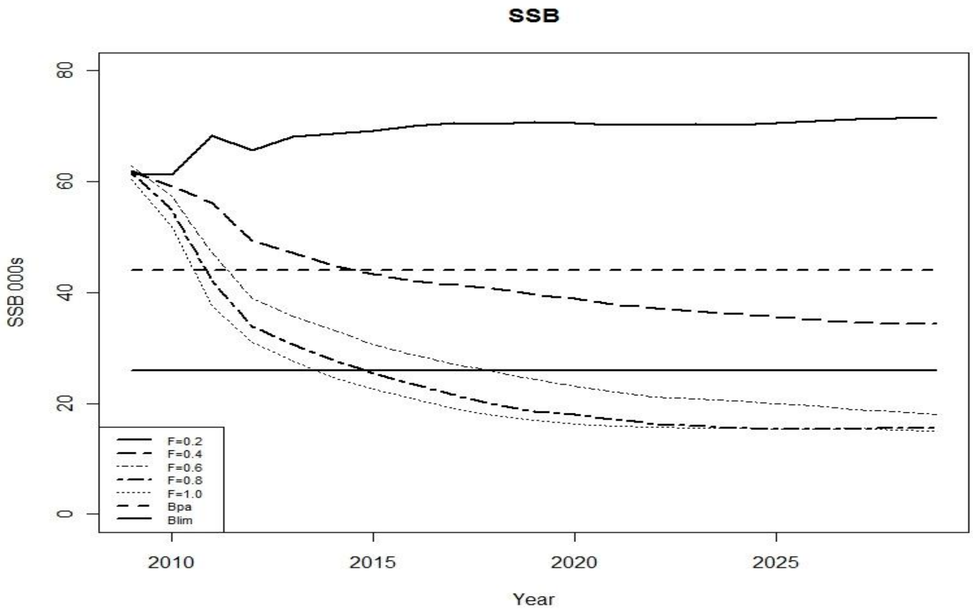


Figure 10. Trajectory plots for broad scale screening exercise (Run 2). Simulated trajectories for SSB.

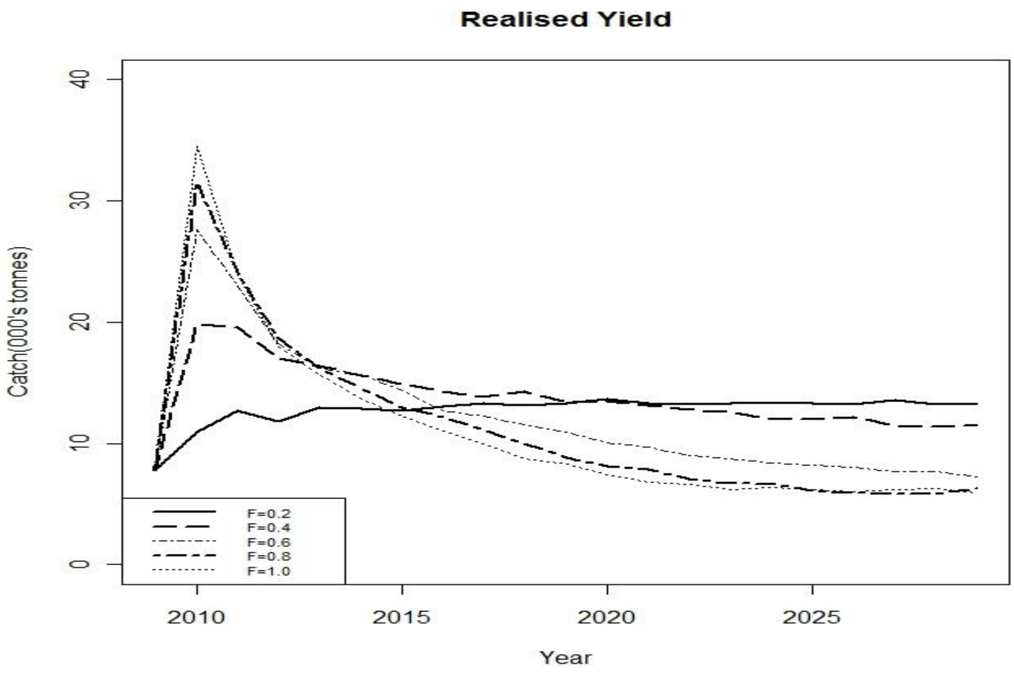


Figure 11. Trajectory plots for broad scale screening exercise (Run 2). Simulated trajectories for realised yield.

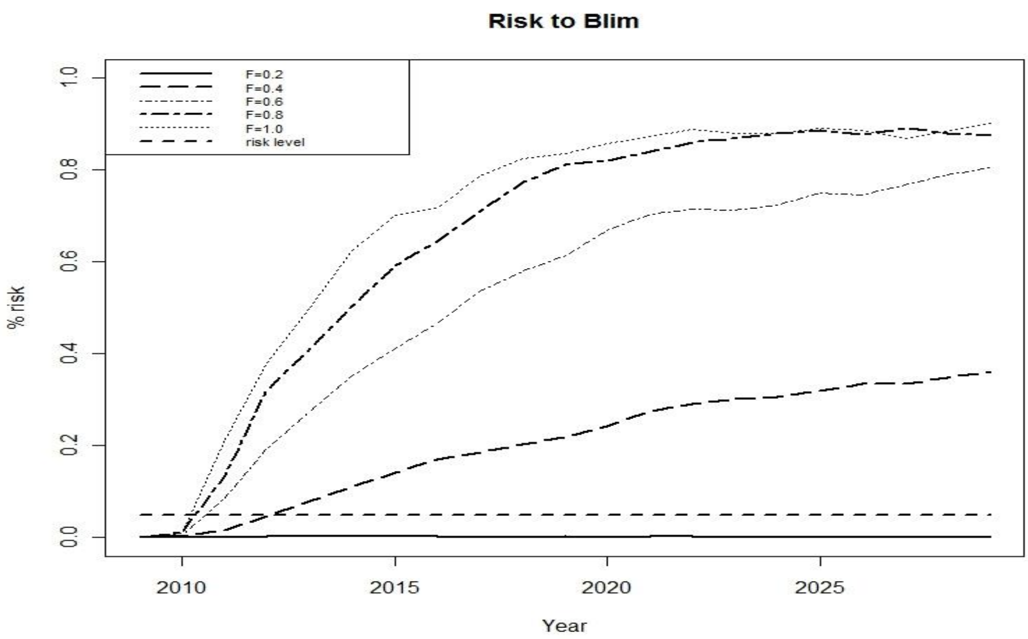
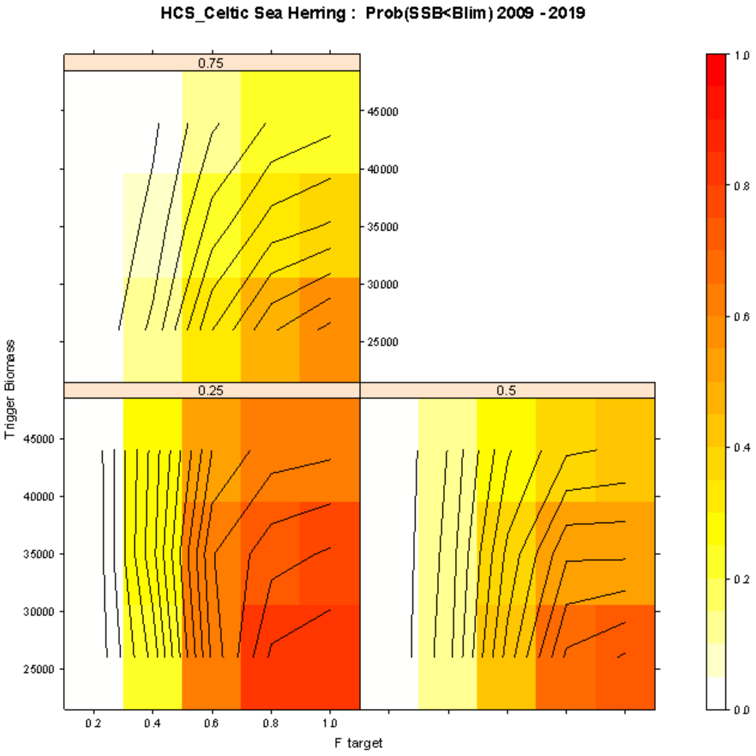


Figure 12. Trajectory plots for broad scale screening exercise (Run 2). Simulated trajectories for risk to $B_{lim.}$ Precautionary 5 % risk level indicated.



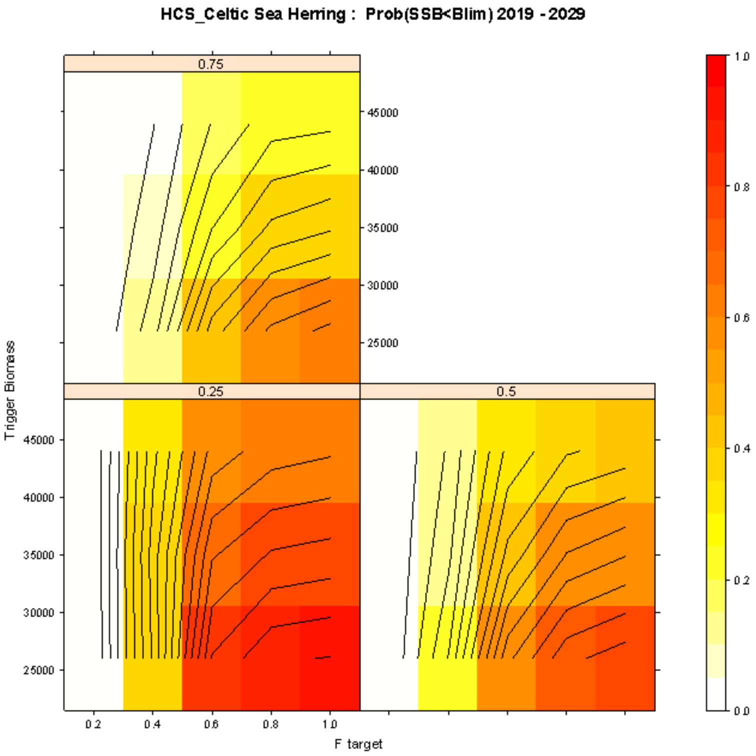


Figure 13. Plot showing the probability that SSB < B_{lim} (Run 2). Risk of being below B_{lim} in the first and second 10-year periods of the simulation. The x-axis shows potential target F over a broad range, and the y-axis the differing levels of trigger biomass. Each line represents a % TAC reduction, to be implemented if SSB <B_{lim} (25%, 50% and 75%).

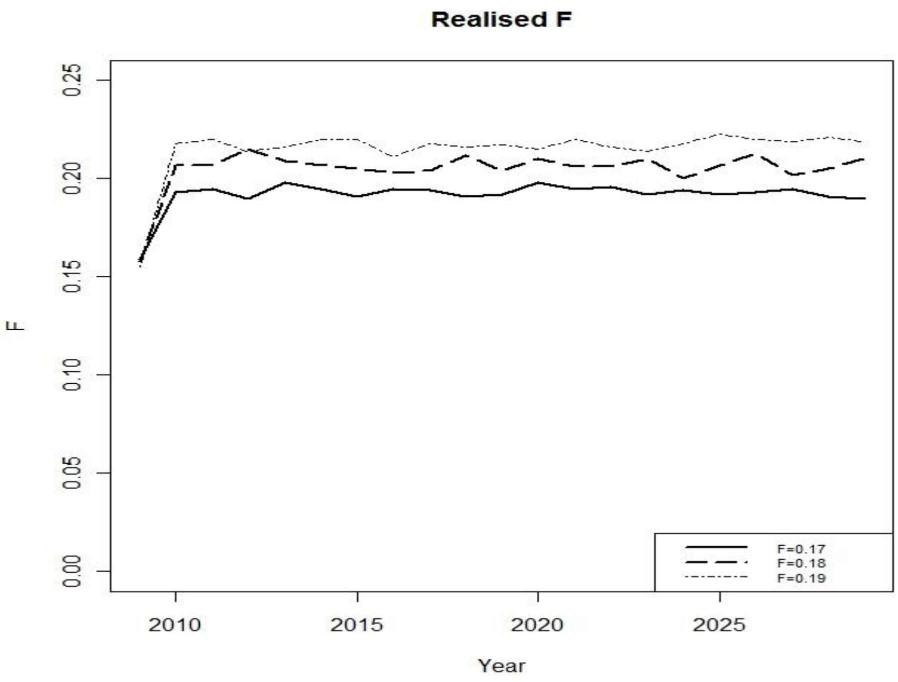


Figure 14. Trajectory plots for simulations of proposed rebuilding plan (Run 3). Simulated trajectories for realised F

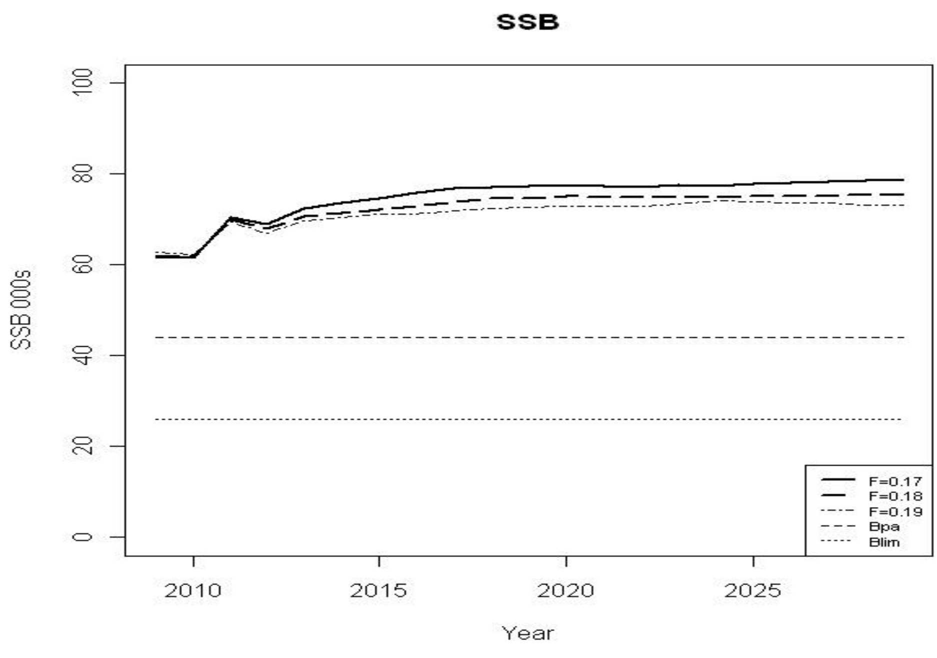


Figure 15. Trajectory plots for simulations of proposed rebuilding plan (Run 3). Simulated trajectories for SSB.

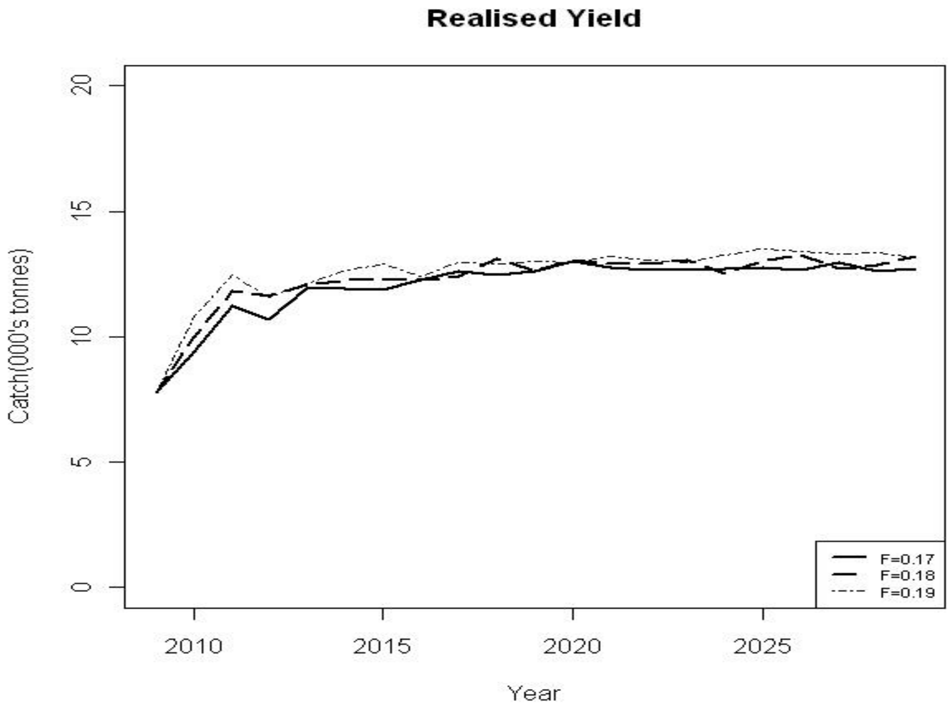


Figure 16. Trajectory plots for simulations of proposed rebuilding plan (Run 3). Simulated trajectories for realised yield.

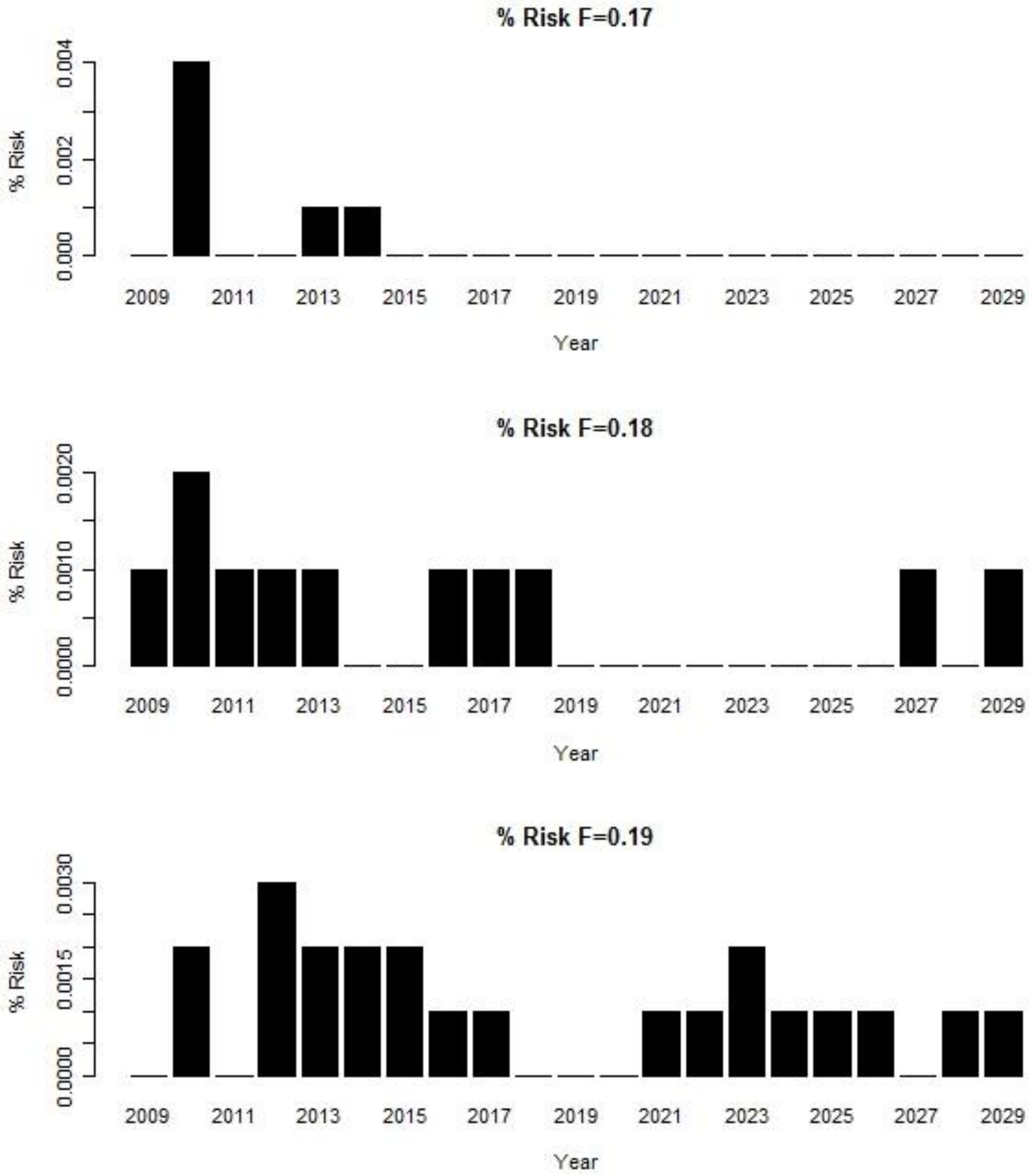


Figure 17. Trajectory plots for simulations of proposed rebuilding plan (Run 3). Simulated trajectories for risk to $B_{lim.}$ Risk to B_{lim} presented as a histogram because of very low levels.

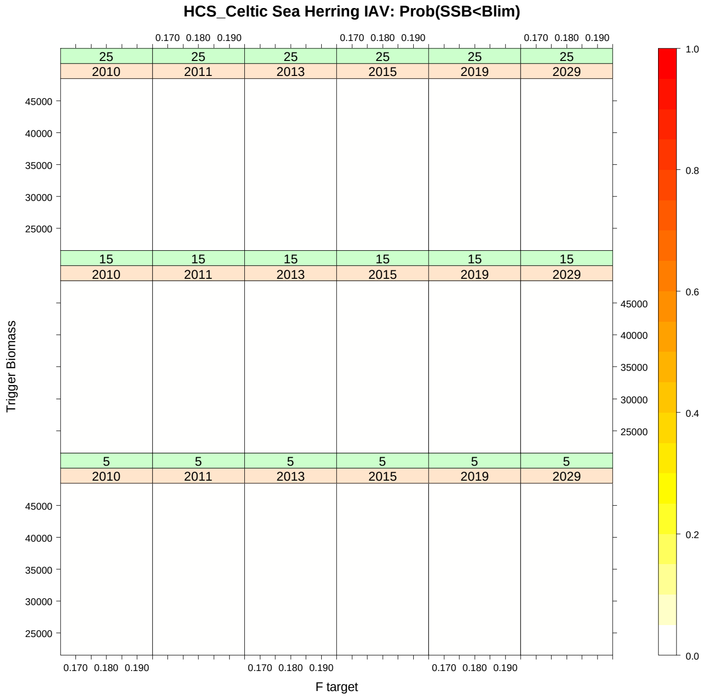


Figure 18. Plot showing the probability that SSB < B_{lim} for sensitivity analysis of the base case to differing inter-annual TAC variations. The x-axis shows potential target F, and the y-axis the differing levels of trigger biomass. Each line represents a % TAC reduction, to be implemented if SSB <B_{lim}.

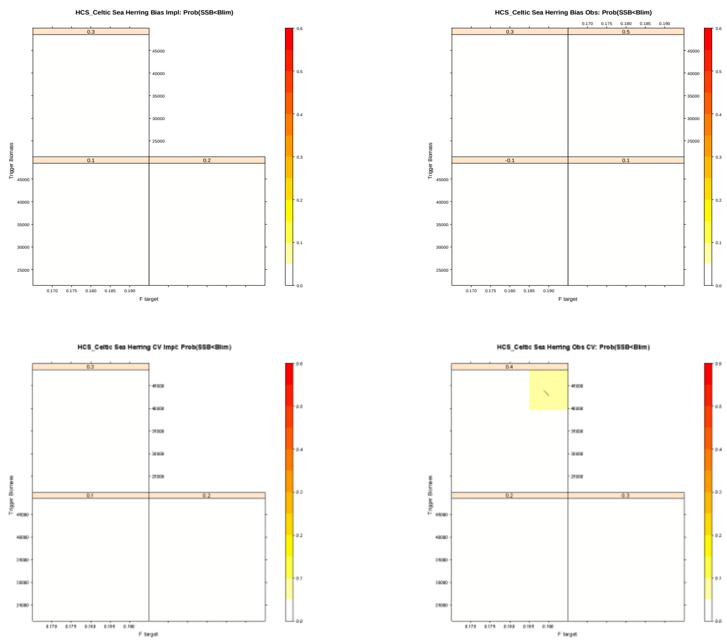


Figure 19. Plot showing the probability that SSB < B_{lim} for sensitivity analysis of the base case to observation and implementation model error (CV) and bias. The x-axis shows potential target F, and the y-axis the differing levels of trigger biomass. Top left to bottom right: Runs 8 (implementation bias), 6 (observation bias), 7 (implementation CV) and 5 (observation CV).

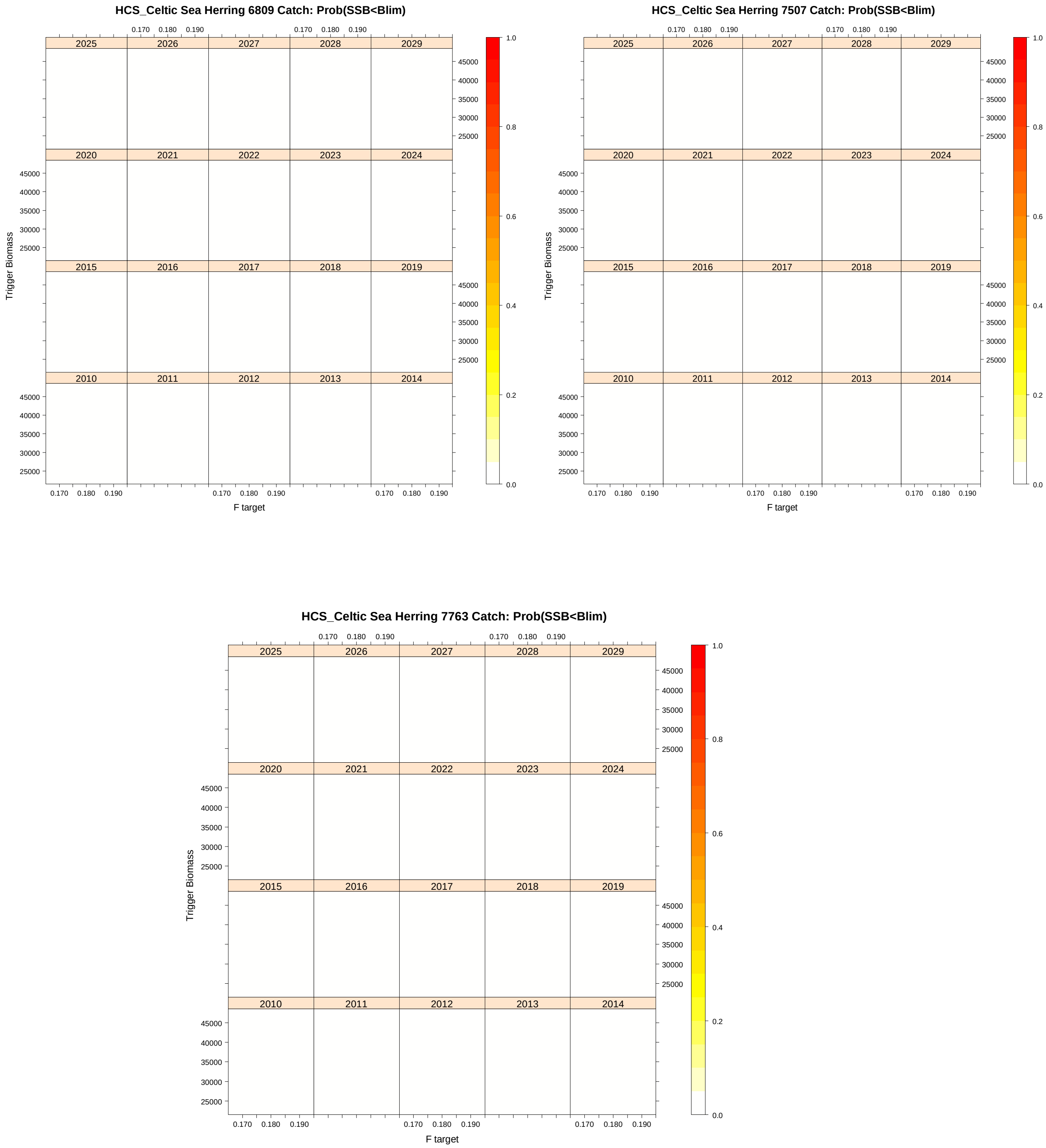


Figure 20. Plot showing the probability that SSB < B_{lim} for sensitivity analysis of the base case to the three most likely interim year catches. The x-axis shows potential target F, and the y-axis the differing levels of trigger biomass. Each plot represents a separate interim year catch.

Acknowledgments

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Appendix 1. Detailed output of base case simulation run.

Target F	Btrig	Year	F	SSB	Catch	TAC	Change	Plim	Pcrash
0.17	26000	2009	0.159	61502	7763	7763	0	0	0
		2010	0.193	61689	9423	9244	8.6	0.004	0
		2011	0.195	70392	11237	11065	17.2	0	0
		2012	0.19	68904	10693	10692	-2.8	0	0
		2013	0.198	72535	11926	11606	7.1	0.001	0
		2014	0.195	73619	11920	11743	2.8	0.001	0
		2015	0.191	74682	11866	11823	0.7	0	0
		2016	0.195	75930	12249	12054	1.6	0	0
		2017	0.194	76897	12597	12246	2.5	0	0
		2018	0.191	77019	12442	12241	-0.6	0	0
		2019	0.192	77461	12632	12471	2.1	0	0
		2020	0.198	77431	13026	12698	2	0	0
		2021	0.195	77316	12759	12382	-2.1	0	0
		2022	0.196	77193	12674	12355	0.1	0	0
		2023	0.192	77547	12679	12467	0.4	0	0
		2024	0.194	77436	12719	12534	0.4	0	0
		2025	0.192	77832	12775	12503	-0.2	0	0
		2026	0.193	78015	12686	12444	0.5	0	0
		2027	0.195	78414	12977	12815	2.9	0	0
		2028	0.191	78531	12635	12417	-3.2	0	0
		2029	0.19	78626	12700	12459	0.2	0	0
0.17	35000	2009	0.158	62161	7763	7763	0	0	0
		2010	0.198	62176	9653	9553	10.9	0	0
		2011	0.195	71179	11336	11209	15.6	0.001	0
		2012	0.193	69654	10999	10824	-2.4	0	0
		2013	0.185	73415	11304	11276	3.9	0	0
		2014	0.195	74954	12227	11907	6	0	0
		2015	0.2	75970	12604	12331	3.4	0.001	0
		2016	0.201	75865	12541	12211	-0.6	0.001	0
		2017	0.197	76350	12633	12337	1.1	0.001	0
		2018	0.194	76575	12568	12237	-0.3	0.001	0
		2019	0.198	76705	12705	12449	1.2	0.001	0
		2020	0.191	77267	12354	12029	-2.3	0	0
		2021	0.195	78062	12773	12519	2.7	0.001	0
		2022	0.192	78410	12691	12391	0	0.001	0
		2023	0.195	78514	12910	12778	2.9	0.001	0
		2024	0.198	78436	13131	12679	-0.9	0.001	0
		2025	0.194	78079	12804	12485	-1.2	0	0
		2026	0.192	78053	12675	12344	-0.7	0	0
		2027	0.196	78357	12976	12697	2.3	0	0
		2028	0.2	77815	13160	12850	0.9	0	0
		2029	0.196	77217	12840	12524	-1.6	0	0
0.17	44000	2009	0.16	61166	7763	7763	0	0	0
		2010	0.206	61309	9806	9554	12.8	0.001	0
		2011	0.201	69457	11266	11098	13.2	0	0
		2012	0.201	68078	10891	10801	-1.6	0.003	0
		2013	0.201	71328	11722	11402	4.3	0.002	0
		2014	0.197	72793	11764	11597	3	0.002	0
		2015	0.208	73896	12520	12141	4.3	0.002	0
		2016	0.199	74811	12232	12049	-1	0.003	0
		2017	0.197	75515	12380	12139	1.3	0.002	0
		2018	0.199	76039	12588	12367	1.3	0.002	0
		2019	0.204	76230	12801	12266	-0.8	0.005	0
		2020	0.2	76422	12606	12488	0.8	0.003	0
		2021	0.199	76731	12673	12288	-0.9	0.003	0
		2022	0.196	76987	12444	12175	-0.2	0.002	0
		2023	0.197	77622	12714	12572	2.3	0.002	0
		2024	0.197	77580	12828	12577	0.4	0.002	0
		2025	0.2	77501	12865	12616	-0.1	0.001	0
		2026	0.196	77411	12800	12478	-1	0.001	0
		2027	0.195	77423	12626	12405	-0.2	0	0
		2028	0.196	77582	12729	12566	0.9	0.002	0
		2029	0.192	77572	12504	12313	-1.5	0.001	0

Appendix 1. (continued).

Target	Btrig	Year	F	SSB	Catch	TAC	Change	Plim	Pcrash
0.18	26000	2009	0.158	61961	7763	7763	0	0.001	0
		2010	0.207	61747	9984	9774	13.9	0.002	0
		2011	0.207	69857	11805	11651	16.4	0.001	0
		2012	0.215	67963	11609	11299	-2.8	0.001	0
		2013	0.209	70715	12062	11822	4.9	0.001	0
		2014	0.207	71432	12243	11995	2.2	0	0
		2015	0.205	72214	12300	12015	0.3	0	0
		2016	0.203	72940	12265	12157	2.2	0.001	0
		2017	0.204	73863	12432	12357	1.8	0.001	0
		2018	0.212	74594	13111	12682	1.5	0.001	0
		2019	0.204	74773	12634	12438	-0.8	0	0
		2020	0.21	75049	13081	12809	1.9	0	0
		2021	0.206	74991	12930	12739	0	0	0
		2022	0.206	74894	12903	12531	-1	0	0
		2023	0.21	75197	13047	12636	1.2	0	0
		2024	0.2	75018	12537	12392	-2.4	0	0
		2025	0.207	75175	13022	12715	2.1	0	0
		2026	0.213	75124	13279	12719	0.2	0	0
		2027	0.202	75163	12733	12565	-0.2	0.001	0
		2028	0.205	75291	12882	12664	0.6	0	0
		2029	0.21	75682	13223	12908	1.5	0.001	0
0.18	35000	2009	0.158	62319	7763	7763	0	0	0
		2010	0.209	62201	10182	9941	15.9	0.001	0
		2011	0.209	70065	11948	11742	13.9	0	0
		2012	0.212	68181	11628	11438	-0.9	0.001	0
		2013	0.211	70939	12111	11868	3.6	0.001	0
		2014	0.219	71455	12706	12380	5.2	0.003	0
		2015	0.214	72318	12603	12364	0.2	0.002	0
		2016	0.205	72791	12242	12042	-1.9	0.003	0
		2017	0.208	73357	12700	12351	2.2	0.002	0
		2018	0.209	73584	12887	12406	0.3	0.001	0
		2019	0.204	73590	12522	12298	-0.7	0.001	0
		2020	0.21	74294	12818	12696	3	0	0
		2021	0.213	74799	13126	12777	0.8	0.001	0
		2022	0.205	74549	12766	12606	-1.7	0.001	0
		2023	0.199	75385	12535	12437	-0.4	0	0
		2024	0.205	76199	13009	12631	2	0	0
		2025	0.208	75732	13195	12895	1.1	0	0
		2026	0.205	75359	12931	12720	-0.4	0	0
		2027	0.209	75084	13205	12842	0	0	0
		2028	0.204	74756	12792	12566	-1.8	0	0
		2029	0.208	74884	12984	12709	1.4	0	0
0.18	44000	2009	0.158	62136	7763	7763	0	0.001	0
		2010	0.206	62044	10058	9908	15.8	0.001	0
		2011	0.209	70258	11871	11712	15.8	0	0
		2012	0.216	68625	11841	11532	-0.9	0.002	0
		2013	0.212	71257	12209	12037	4	0.003	0
		2014	0.216	71702	12517	12186	1.6	0.004	0
		2015	0.217	72282	12601	12248	0.8	0.006	0
		2016	0.216	72974	12772	12330	0	0.006	0
		2017	0.219	73408	12857	12567	1.8	0.006	0
		2018	0.214	73806	12814	12604	0.3	0.005	0
		2019	0.212	74001	12793	12677	0.5	0.005	0
		2020	0.216	74563	12954	12656	0	0.005	0
		2021	0.213	74946	13016	12748	0.4	0.007	0
		2022	0.213	74829	12973	12706	-0.7	0.006	0
		2023	0.216	74868	13177	12773	0.7	0.005	0
		2024	0.212	74675	12878	12689	-0.3	0.005	0
		2025	0.208	74882	12907	12681	-1	0.005	0
		2026	0.214	74741	13116	12736	0.6	0.006	0
		2027	0.211	74515	13038	12857	0.4	0.003	0
		2028	0.214	74642	13190	12868	0	0.002	0
		2029	0.212	74829	12912	12710	-0.5	0.001	0

Appendix 1. (continued).

Target F	Btrig	Year	F	SSB	Catch	TAC	Change	Plim	Pcrash
0.19	**26000**	2009	0.155	62930	7763	7763	0	0	0
		2010	0.218	62427	10797	10621	21.8	0.002	0
		2011	0.22	69566	12448	12284	13.3	0	0
		2012	0.214	66959	11571	11491	-5	0.003	0
		2013	0.216	69767	12143	11928	3.1	0.002	0
		2014	0.22	70570	12618	12418	5.7	0.002	0
		2015	0.22	71204	12904	12485	-1.1	0.002	0
		2016	0.211	71328	12410	12252	-0.3	0.001	0
		2017	0.218	72048	12934	12674	3.1	0.001	0
		2018	0.216	72394	12927	12645	-0.2	0	0
		2019	0.217	72584	13012	12723	1.1	0	0
		2020	0.215	72824	12943	12788	0.4	0	0
		2021	0.22	72858	13222	12991	1.4	0.001	0
		2022	0.216	72998	13034	12861	-0.6	0.001	0
		2023	0.214	73454	12978	12754	-1	0.002	0
		2024	0.218	74060	13268	12946	1.8	0.001	0
		2025	0.223	73937	13500	13164	1.5	0.001	0
		2026	0.22	73794	13416	13108	-0.1	0.001	0
		2027	0.219	73582	13280	13027	-0.6	0	0
		2028	0.221	73266	13362	13066	-0.5	0.001	0
		2029	0.219	73091	13167	12907	-0.3	0.001	0
0.19	**35000**	2009	0.161	61051	7763	7763	0	0.001	0
		2010	0.22	61015	10540	10379	19	0.003	0
		2011	0.233	68491	12621	12308	16.6	0.001	0
		2012	0.229	66282	11850	11594	-4.5	0.004	0
		2013	0.228	69327	12488	12140	3.5	0.007	0
		2014	0.224	70431	12614	12424	2.8	0.006	0
		2015	0.227	70732	12916	12602	1.4	0.007	0
		2016	0.229	70821	13123	12767	1.3	0.005	0
		2017	0.232	70922	13238	12829	0.5	0.006	0
		2018	0.224	70706	12806	12624	-1	0.005	0
		2019	0.218	70840	12635	12419	-1.3	0.004	0
		2020	0.223	71334	12959	12793	2.4	0.002	0
		2021	0.22	71533	12854	12604	-0.6	0.001	0
		2022	0.222	71750	12919	12698	0.4	0.002	0
		2023	0.223	71954	13141	12742	1.1	0.004	0
		2024	0.224	72042	13040	12767	0.1	0.002	0
		2025	0.219	72501	12811	12712	0	0.002	0
		2026	0.22	72875	13143	12883	0.9	0.002	0
		2027	0.217	72736	13081	12898	0	0.001	0
		2028	0.218	72837	13124	13065	1.3	0.001	0
		2029	0.216	73021	12975	12823	-1.3	0.002	0
0.19	**44000**	2009	0.157	62139	7763	7763	0	0.001	0
		2010	0.222	61604	10720	10541	20.3	0.002	0
		2011	0.224	68915	12341	12128	14.2	0.002	0
		2012	0.236	66397	12333	12154	0.3	0.001	0
		2013	0.237	68375	12455	12227	0.1	0.003	0
		2014	0.234	68522	12481	12149	0.8	0.006	0
		2015	0.231	69238	12661	12516	2.5	0.005	0
		2016	0.226	69949	12465	12256	-1.4	0.004	0
		2017	0.222	70267	12612	12483	1.1	0.005	0
		2018	0.226	70671	12927	12757	1.9	0.004	0
		2019	0.225	71082	12910	12547	-1	0.003	0
		2020	0.224	71498	12898	12757	1.4	0.003	0
		2021	0.226	71389	13023	12789	-0.6	0.002	0
		2022	0.229	72163	13101	12746	0	0.002	0
		2023	0.235	72323	13562	13120	1.6	0.004	0
		2024	0.231	72388	13239	13095	0.2	0.003	0
		2025	0.233	72393	13390	13114	0.3	0.004	0
		2026	0.234	72414	13564	13198	0.7	0.005	0
		2027	0.228	72125	13235	13001	-2	0.005	0
		2028	0.233	72359	13399	13028	1	0.005	0
		2029	0.226	72192	12965	12737	-1.8	0.003	0

Appendix 2a. Review #1 of the Celtic Sea Herring management plan evaluation

1. Is the study based on a correct interpretation of the management plan*?

This study integrates mainly points 2 and 3 of the EU policy statements.

Point 2: “In 2010 and subsequent years, the TAC shall be set equal to a fishing mortality of F0.1.” . F0.1 = 0.17 and 0.19 were integrated as input parameters for the simulations therefore this point is fully implemented into the modeling framework used for this study.

Point 3: The discussion section of this study clearly explains how point 3 “the catch should be reduced to the lowest possible level, the TAC for the following year will be reduced by 25%” has been interpreted in the study. The wording of the EU policy statement is misleading but the interpretation of this clause appears to be correct: if SSBtacyear<Blim , A 25% reduction in TAC is applied.

Points 4 and 5 deal with the closure of VIIaS. Considering the possible migrations between areas, it would have been interesting to make an attempt to consider how the closure of this area may or may not reflect on the short term scale on VIIj. That, however, could have added another factor of uncertainties.

Points 1, 6 and 7 were not points to be discussed/implemented in the management plan.

2. Have the authors presented the correct information for evaluating the precautionary nature of the plan?

The authors focused on the following criteria to evaluate the plan : the probability of SSB falling below Blim, Realized F, catch, SSB and risk to Blim. Those parameters are sufficient to understand what the plan may imply for the stock and its harvesting.

The presentation of the results however lacks of a sound temporal limit which also reflects the lack of temporal limit in implementation of the EU policy statements. From a modeler point of view, on figure 6.3, most runs tend towards some steady states situation past 2019 and until the end of the runs in 2029. The occurrence of steady-state situation in nature is itself a nearly philosophical debate among scientists. Here, considering the variation in recruitment on a short term species and all the potential factors that may affect the fishing efforts (adjustment in fleets due to gas price for example), estimating the state of the stock without too much errors is probably only possible for a few number generations (e.g. 3-4). In that sense, going past 2019 may be misleading as a quick reading of the plots may suggest people outside of the modeling world that things will be nicely steady after 2019 which is not realistic as this situation is more a signal from the model structure rather than the natural variations of its parameters (biology, harvesting, environmental factors…). This could be avoided by limiting all plots to 2019.

3. Are the assumed stock dynamics an adequate basis for simulating the plan?

The discussion section of this study mentions the problems identified in the assessment methodology (i.e. benchmark). The general impression is that the authors are aware of the problems and of some of the solutions to explore to solve them. However, no exploratory/sensitivity analyses were made to evaluate the impact of those factors. The reason was mainly the lack of knowledge/data of some aspects or the fact some of those points were usually not considered into the assessments. The stock dynamics does not include the effect of mixing from adjacent area as this point is considered to add some uncertainty. However, this discussion gives the overall impression that the stock dynamics is well relatively described considering the current knowledge on the fisheries.

Dealing with the stock recruitment relationship is a source of issues due to the variability of the recruitment between years. The authors mentioned any of the classical models were applicable but no indication of the quality of the fitting of those relationships was provided (such as r^2 or AIC). A similar S-R situation has been observed with the Bay of Biscay anchovy long term management plan (STECF, 2008) and none of the regular models were apparently applicable as well. In practice, all models for BoB anchovy had the same AIC which meant that none of the model was performing better than the others therefore the adjustment was quite poor. In that case, choosing the most convenient (i.e the least worst) model may be based on some criteria such as the shape or the number of parameters. Here, the segmented regression is simpler to use than any curvilinear approach and still provides more or less the same (poor) adjustment.

A closer look at figure 3 (S-R) shows the stock has been quite low in recent years but recruitment has been very variable. Data go back to 1958 and up to 2006. Considering the recent biomass of the stock, fitting the S-R relationships for the whole time series may put too much weight on past biomass situations. The authors explain however that the fitting on the whole time series provides some robust results.

Under the scrutiny of different neutral eyes, any attempt to fit a relationship on those points may result in different approaches/point of view. It would have been interesting to have a better explanation of this choice of segmented regression and maybe a sensitivity analysis using another descriptor/relationship for S-R.

4. **Are the assumed fleet dynamics an adequate basis for predicting future catches and fishing mortality in the simulation?**

The fleet dynamics is not explicitely mentioned in this study as the total catch is ruled by the Harvest Control Rules (HCR) through the automatic TAC set by the estimates of SSB. The activity of the fleet is not simulated. The closure of VIIaS and its possible effects on the redeployment of the local fleet are not integrated into this study as well. Considering the distances between areas, it is hard to tell if integrating that measure into this plan would have affected the biomass in VIIj.

5. **Has an appropriate model formulation been used?**

The general procedure used for this study is more or less standard and is described with details in the “Materials and Method” section. From an outsider point of view, the information is detailed enough to understand the approach taken. The procedure itself seems fine for the task (the same principles have been applied on some other MSE e.g. North Sea Cod).

6. Have all sources of process and estimation error that could impact the conclusions been adequately represented?

The major sources of uncertainties for this stock have been reviewed in this study in the discussion section (see answers #3 and #4).

One source of error apparently not accounted into this study remains using the most recent assessment as a starting point for the simulations. The Benchmark report (Cadrin et al., 2009) mentions that the assessment model lacks of performance diagnostics (e.g. the screening of possible retrospective pattern). Considering the various sources of uncertainties from the data and from the performance of the model, it would have been interesting to test the behavior of the Management plan for different starting years (for example, the assessments for the last 5 years). I suspect as the management plan converge towards steady-state on the long run that the plan, overall, is not strongly affected by some possible biases in the initial conditions of the simulation. However, as this plan is more oriented towards a short-term situation, there may be some significant changes in the first years simulated.

7. Are the authors' conclusions valid?

The modeling framework provides the usual responses one can expect from looking for the compromise between protecting and harvesting the stock: setting higher Btrigger is a protective measure and lowering F reduce the risk of collapse. The management plan is qualitatively sound on these mandatory aspects. Overall, the author's conclusions from the simulations appear to be valid. The sensitivity analysis which goes through various value of F and reductions of TAC is helpful to test how precautionary the 25% TAC reduction rule and F target (0.17-0.19) are in comparison to other values.

In the discussion, the paragraph "point 3 may not be…" is too concise to explain why the 25% TAC reduction should not be in a long term management plan.

Note: on figures 8.1, 8.2, 8.3, it would have been helpful to tell that probabilities are very low. For the quick reader, it seems like no plot has been correctly produced.

8. Has the request been answered in full?

The request has been answered in full for points 2 and 3 which were the only points ICES was asked to evaluate. The authors dealt with the consequence for catch and stock biomass of the implementation of the points 2 and 3, the limit of use of those rules to remain within the precautionary approach and to sustain maximum yield. The simulations also provide time series of the evolution of SSB, F, TAC and risk to be below Blim (although as I wrote earlier, the temporal extension after 2019 might be misleading). All those points were in the EU request letter*.

Through the sensitivity analysis, the authors went further than the initial request by exploring the risks associated with a wide range of target F (0.2-1) and higher reduction of TAC (50-75%). This kind of initiative is also within the EU request letter as ICES was "invited to propose alternative rules or modified rules on its own initiative or in consultation with RACs and to evaluate these"

*:(see http://groupnet.ices.dk/HAWG2009/Celtic%20Sea%20Herring/Commision%20reply%20_Celtic%20Sea%20RebPlan.pdf)

References:

Anon. , 2008. Report of the STECF Meeting on long-term anchovy management. STECF. 77p + annex.

Cadrin, S., Pawlowski, L., Goethel, D. and Kerr, L. 2009. Benchmark review of Celtic Sea Herring. Unpublished report to ICES ACOM. 9 pp.

Appendix 2b. Review #2 of Celtic Sea management plan, 9th June 2009

The proposed management plan for Celtic Sea (Zones VIIhjk):

1. For 2010 and subsequent years the TAC will be set consistent with a fishing mortality rate of F0.1 = 0.19.
2. If, in the opinion of ICES and STECF the catch should be reduced to the lowest possible level, the TAC for the following year will be reduced by 25%

(With additional restrictions not tested)

The EC requested the evaluation should address:

1. the consequences of implementing the above rule instead of implementing ICES' current advice for this stock according to the precautionary approach;
2. the extent to which the application of this rule would deliver management in conformity with the precautionary approach;
3. the extent to which the application of this rule would deliver maximum sustainable yield from the stock;
4. where possible, stochastic future time-streams of TACs and fishing effort necessary to catch those TACs should be made available to STECF for economic analysis.

ICES has requested a review based on the 8 clauses

1. Is the study based on a correct interpretation of the management plan*?
2. Have the authors presented the correct information for evaluating the precautionary nature of the plan?
3. Are the assumed stock dynamics an adequate basis for simulating the plan?
4. Are the assumed fleet dynamics an adequate basis for predicting future catches and fishing mortality in the simulation?
5. Has an appropriate model formulation been used?
6. Have all sources of process and estimation error that could impact the conclusions been adequately represented?
7. Are the authors' conclusions valid?
8. Has the request been answered in full?

The review below is organised around these eight clauses and a brief look at the questions raised by the EC.

1. Correct interpretation

The plan appears to be correctly interpreted, though the diagram in Figure 1 is a poor representation of the process.

2. Correct information on the performance of the plan.

Figure 7.1 provides the basic information on the precautionary performance of the plan as simulated. Blim is specified at 26,000 t on the basis of lowest observed SSB, however, with a well established breakpoint at 41,600 t in the S/R relationship (see below) there are indications this may be miss specified. Nevertheless current specification is at 26,000 and ICES criteria of 5% are correctly dealt with.

3. Adequacy of the assumed stock dynamics

The fitted S/R relationship and input data are given in Figures 3 and 5. A example of the simulated data are given in Figure 4. The fitted model appears to be an adequate single model description of the historic stock and recruitment. The choice of model is plausible and well supported by the data, the fitting method is suitable to give a good fit between data and model. The SSB breakpoint is well described by the data and the value of SSB at the breakpoint and mean recruitment above the breakpoint are well established. The diagnostics indicate that the S/R data are stable over time and therefore the use of the fitted model to infer the future is reasonable. There are indications of slight deviation from the model below the breakpoint, but this does not substantively influence any aspect of the results.

The clipping of simulated values appears appropriate (Fig 4) but its unclear over which biomass values the comparison of simulated and predicted have been compared (normal practice would be to use only the observed SSBs hopefully this is what is presented). The report states that the model predicts higher recruitment from 0.2 to 0.5, but Fig 4 seems to show the reverse. No mention is made of a year on year correlation in recruitment, though this seems evident in the timeseries.

In conclusion the S/R model appears well founded with the exception of autocorrelation and thus may be classed as marginally adequate.

4. Adequacy of assumed fleet dynamics for predicting future catches and fishing mortality in the simulation?

No description is provided to describe fishery dynamics, though the use of implementation CV and bias of 20% and 10% seem reasonable (or too uncertain) given the recent history of fishing. The mismatch between TAC year and fishery and assessment implies some flexibility between years. Evaluations of between year flexibility (Methods 2008) suggest this is not a problem for low exploitation rates such as those proposed. Control through TAC would seem to be effective based on data in the ICES stock summary sheet (ICES 2008)

5 Appropriateness of model formulation

The software used was supplied from the ICES website and has been validated by use on other similar simulations.

Parameterisation of the model is rather superficial, ignoring any autocorrelation in either recruitment or measurement error, though both are available in the software. This simple approach does not include an evaluation of assessment error, or correlation in that error. Given that the evaluation was for one specific harvest rule with only one survey to tune the assessment and that assessment model used (FLICA) is available in FLR it would be feasible to carry out a fuller evaluation. At the least it would be helpful to check the characteristics of error in the assessment in a small number of runs of a single case.

6 Have all sources of process and estimation error that could impact the conclusions been adequately represented?

The basis for fishery dynamics and the implementation error is poorly described in the report. This base case assumes 20% CV on implementation and observation, and a 10% bias on implementation. While these figures are plausible, there is little presented in the document to back this up. Examination of the ICES ACOM advice sheet for Celtic Sea herring indicates that the catches recorded (and included in the data used for the S/R model) are below the TAC in the last 12 years. Suggesting that the values assumed for bias and CV on implementation may overestimate these errors.

The recent survey seems to perform well but the timeseries may be a bit short to determine errors well. Once the survey is compared with a converged VPA errors may be more reliably established, though this will not be possible for several more years. In this case choice of 20% CV may be over optimistic for a single vessel acoustic survey.

A sensitivity analysis to observation and implementation bias is provided, these vary from from -0.1 to 0.5 and .1 to 0.3 respectively. Similarly observation and implementation CV is varied from 0.2 to 0.4 and 0.1 to 0.3 respectively. These provide a fairly simple and effective approach to evaluating if the results are critical to the assumptions.

This sensitivity analysis shows risks are not significant except for observation CVs of 0.4 at Fs above 0.185. However, the investigation does not cover higher CVs and higher implementation bias combined.

Nevertheless the insensitivity of the conclusions to plausible if simplistic errors is such that this is an adequate approach in these circumstances. This would not be the case if the results were more marginal.

7 validity of authors' conclusions

The authors conclude that from the current starting point fishing at F0.1 (0.17 to 0.19) is in accordance with the precautionary approach, this is supported by the analysis.

Some concern is expressed that previously observed catches may be too high to sustain a 25% restriction on TAC. However, if the target F of ~ 0.18 a 25% is complied with (within 10% bias and 20% CV) then the 25% should be acceptable unless a very long run of poor recruitment occurs. However, because autocorrelation has not been included in the simulated S/R relationship and SSB does not fall below Blim during simulations at F=0.17-0.19 the consequences of applying 25% with SSB below Blim are not tested and not know.

The conclusions are based on the current PA points which might benefit from re-evaluation

8 Has the request been answered in full?

In addition to the questions raised by ICES the EC asked the following:

-1. the consequences of implementing the above rule instead of implementing ICES' current advice for this stock according to the precautionary approach;

The rebuilding plan proposed might result in slower recovery than that obtainable by following ICES precautionary advice of no directed fishery. However, currently this ICES advice does not seem to be being followed (see ICES stock summary sheets), so the plan may be lead to recovery more quickly than NOT following ICES precautionary advice.

2. the extent to which the application of this rule would deliver management in conformity with the precautionary approach;

The simulations show that the plan is precautionary within the ICES definition (risk <5% SSB below Blim). The evaluation was limited in scope ignoring some aspects that may be important but as a sensitivity analysis using more demanding conditions of bias and error was carried out and also show acceptable performance. Thus given the relatively low exploitation rate (F=~0.18) limitations are acceptable and the conclusion that the plan is precautionary is reasonable.

The inclusion of a 25% inter-annul restriction on reduction in TAC given SSB below Blim is not testable within the range of recruitment simulated, as the F target does not bring the stock to Blim to allow this to be tested. Any test if this would be artificial. Nevertheless it is expected that such a restriction is acceptable as the exploitation rate implied by F-0.18 is lower than the 25% restriction thus TACs should come down faster than the stock.

3. the extent to which the application of this rule would deliver maximum sustainable yield from the stock;

The plan is designed to give fishing at F0.1. Based on yield per recruit studies presented in HAWG (ICES 2009), Celtic Sea herring has no defined Fmax within a plausible range of F. In the absence of Fmax, F0.1 forms a good surrogate for Fmsy.